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Chi, Nan; Carlsson, Birger; Holm-Nielsen, Pablo Villanueva; Peucheret, Christophe; Jeppesen, Palle

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Dispersion management for two-level optically labeled signals in IP-over-WDM networks

Nan Chi, Birger Carlsson, Pablo V. Holm-Nielsen, Christophe Peucheret, Palle Jeppesen  
COM Center, Technical University of Denmark, Building 345V, Lyngby DK-2800, Denmark  
Tel: +45 4525 3782, Fax: +45 4593 6581, E-mail: nc@com.dtu.dk

**Abstract:** The transmission characteristics of a two-level optically labeled signal with ASK/DPSK modulation are investigated under varying dispersion management. A limitation of extinction ratio and the resilience of fiber span, compensation ratio, and power level are obtained.

Introduction

Rapid converging of telecommunicaiton and data communication networking drive the future ultra-high speed data-centric network evolving into an IP networking on a WDM physical infrastructure [1]. With respect to efficiency and cost effectiveness, new switching technologies are required to merge the intermediate layer such as ATM and SDH and to route individual packets without converting the packet from optical to electrical format. Although the optical wavelength can serve as an optical label in MP \$ scheme, a second level of optical label is still necessary for provisioning, maintaining, and restoring switched light-paths. This second level optical label can be approached by a sub-carrier modulation [2] or by an orthogonal modulation format [3] combining ASK and DPSK modulation in a single carrier.

In this paper, two-level optically labeled signals with orthogonal ASK/DPSK modulation are modeled and the transmission characteristics under different dispersion map, span length, degree of compensation and input power level are investigated for the first time. The maximum value of extinction ratio of the payload is found at 9.53dB. Very low eye opening penalty (EOP) and considerable resilience of input power level up to 25dB are demonstrated in the pre- and hybrid compensation scheme.

Principle

The orthogonal ASK/DPSK modulation format proves the possibility of deploying two-level optical labeling. The wavelength of the ASK modulated packet serves as its own first level label, and the second level label is achieved by modulating the label information orthogonal to the packet data, i.e., by modulating the phase of the optical carrier. In the network nodes, the wavelength and/or the orthogonal modulated label are used for routing the packets, and can be swapped.

In our system an intensity modulated payload at 10 Gbit/s accompanied by a DPSK modulated label at 2.5 Gbit/s is considered. The ASK and DPSK modulation are realized by a Mach-Zehnder modulator and a phase modulator, respectively. A 1-bit delay Mach

-Zehnder interferometer is used for the DPSK demodulator. The system setup of two-level optically labeled signal transmission is shown in Fig.1.

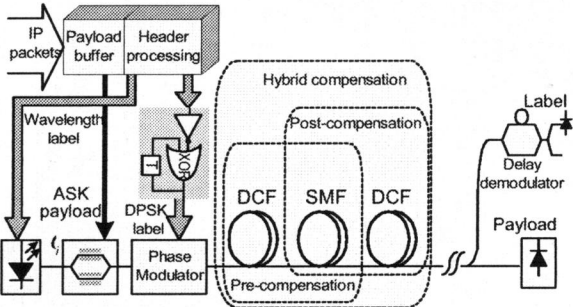


Fig.1 Transmission setup of two-level optical labeling system.

In order to detect the DPSK label, a limited extinction ratio is required, which is unlike a traditional intensity modulation optical communication system, where high extinction ratio is preferred. An ASK/DPSK modulated signal with finite extinction ratio can be expressed in Equation (1), Where the mark 'p' is for the payload and 'l' is for the label, respectively, q the data sequence, T the period, g the pulse shape. The extinction of payload is  $10\log(\epsilon)$ , Suppose the pulse shape of the label is square, five distinguishing power levels are obtained at the output of the label demodulator depending on different possibility of payload data and label data, as shown in Table 1.

Table 1 Output power of label at different combination of the payload data and label data.

Label $q_{l,n}$	Payload $q_{p,4n}, q_{p,4(n+1)}$	Output power of label
1	1, 1	$g_p(t)$
	1, 0 and 0, 1	$\frac{g_p(t)}{4} \frac{H}{4} \frac{\sqrt{g_p(t)}}{2}$
	0, 0	H
0	0, 1 and 1, 0	$\frac{g_p(t)}{4} \frac{H}{4} \frac{\sqrt{g_p(t)}}{2}$
	1, 1 and 0, 0	0

$$S(t) = \sum_n \int_{-\infty}^{\infty} H f(1 - H q_{p,4n} m g_p t (4n - m) T_p) \exp i \sum_l (1 - q_{l,n}) g_l(t - n T_l) dt \Big|_{-\infty}^{\infty} \quad (1)$$

$\approx$

$\approx$

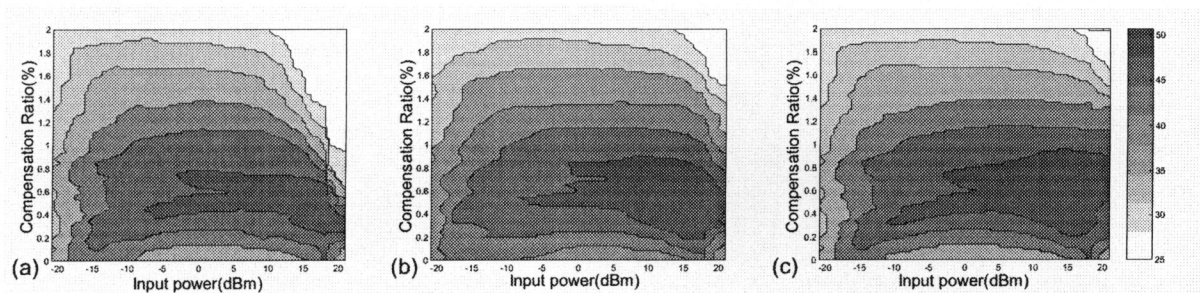


Fig.3 Contour plot of EOP for the payload as a function of Input power and compensation ratio for (a)post-compensation, (b) pre-compensation and (c) hybrid compensation.

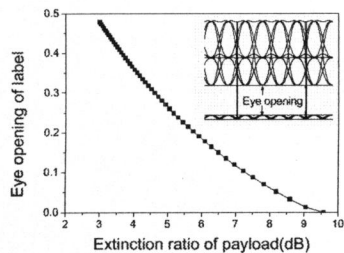


Fig.2 The output eye opening of label versus extinction ratio of payload, the inset figure shows the multi-level eye diagram of detected label.

Then the eye opening of this eye diagram multi-level label can be derived from table 1, which has a simple expression as  $(5 H1)/4$ . The output eye opening of label as a function of extinction ratio of payload is shown in Fig.2. To obtain an open eye the extinction ratio of the payload must be no larger than 9.53dB. According to this limitation to extinction ratio induced by the label as well as the requirement for good detection of the payload, we apply 6dB in the following analysis.

Transmission performance

Ideally, the payload in ASK format is independent of the DPSK-modulated label, but in reality, there are complex interactions between the two orthogonal channels during fiber transmission, which stems from the fact that the self phase modulation of the ASK payload due to the fiber nonlinear effect give rise to phase noise on the label, and in turn, the phase noise can be converted into the intensity fluctuation of payload through fiber dispersion. Therefore distinct transmission characteristics of the ASK/DPSK modulated signal can be predicted and detailed dispersion and nonlinear effect must be included in the simulation.

We investigate varying fiber span consisting of standard single mode fiber (SMF) compensated by dispersion compensation fiber (DCF) at different degree. The EOP performance of the payload in the post-, pre- and hybrid compensation scheme depending on SMF length, compensation ratio and input power are demonstrated in Fig.3. Hybrid and

pre-compensation show a good tolerance to power level (up to 25dB) and compensation ratio when the normalized EOP is below 5 dB. The optimum compensation ratio in these three cases is found less than 100% and decreases when increasing the SMF length. The lowest penalty of the payload is obtained in the pre-compensation scheme. No distinct in the transmission performance of the label is observed in all three cases. Fig.4 gives the EOP performance of the label in hybrid compensation scheme. It is also found that although the DCF can improve the eye opening of the payload, the label will always be degraded no matter which compensation ratio is selected.

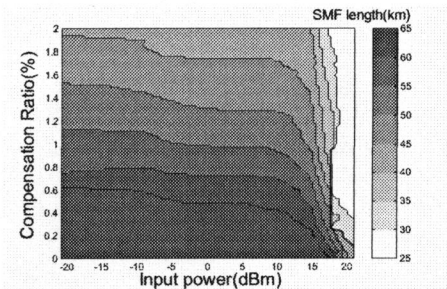


Fig.4 Contour plot of EOP for the label depending on input power and compensation ratio at hybrid compensation scheme.

Conclusion

We have studied the transmission performance of the two-level optically labeled signal with an orthogonal ASK/DPSK modulation format. The extinction ratio must be less than 9.53dB to get an open eye of the detected label. Hybrid and pre-compensation scheme show a considerable power level resilience.

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